[Proc. Roy. Soc. Victoria, 43 (N.S.), Pt. II, 1931.]

Art. XI.—*Alkaline Tertiary Rocks near Trentham and at Drouin, Victoria.*

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(With Plate VII.)

[Read 9th October, 1930; issued separately 20th January, 1931.]

Trentham is situated about 60 miles north-west of Melbourne, close to the main divide, and is 2,260 ft. above sea level. In this district a belt of Newer Volcanic rocks extends east and west between Kyneton and Daylesford, along and just north of the divide, with northerly extensions along the valleys of the Campaspe, Coliban and Loddon Rivers and Kangaroo Creek. Alkaline rocks have been recorded from various localities from Mt. Macedon to Daylesford (3, 5 and 8), a distance of about 30 miles from east to west. In the neighbourhood of Trentham the volcanic rocks include olivine-basalts, olivine-anorthoclase-basalts, trachytes and pitchstone, basaltic types being apparently much more abundant than the others. Mr. H. Foster is engaged in mapping the district, and a systematic petrographic examination of his specimens may settle this question. Many of the volcanic rocks are converted into deep soils.

Some of the numerous points of eruption are hills formed mainly of lavas and others of scoriae. Mount Wilson, Babbington's Hill and Blue Mountain are examples of trachytic lava hills; Spring Hill and Mount Franklin are basaltic scoria cones.

Eucalypt leaves which McCoy(4), who described them, considered to be of Pliocene age, have been found in sub-volcanic deep leads during mining operations. The moderate amount of erosion affecting the volcanic rocks and the survival of scoria cones support McCoy's opinion.

Extensive faulting and vertical earth-movements occurred a few miles to the south during the Tertiary period (2). The age of the faults has not been definitely established, but the Greendale fault is younger than the *Laurus Werribeensis* beds (Miocene?).

The rocks described below have already been noted by Professor Skeats and by E. J. Dunn(1 and 7). Good analyses are now available, and more detailed petrographic descriptions than have yet been published are given below.

Mount Wilson is a hill composed of anorthoclase-trachyphonolite, about 3 miles south of Bullarto, near the heads of the Lerderderg and Werribee Rivers, on the southern edge of the volcanic area. The surrounding rocks are deeply entrenched by narrow valleys, and the lava from this centre of eruption seems to be of small extent. The rock is dark greenish grey, fine-grained, compact and free from vesicles. It contains a few felspar phenocrysts about ½ in. long. It has a tendency to fracture in one direction, apparently due to flow structure. No tuffs were noted.

Two samples were taken for analysis, one from the top and the other from the north-western flank of the hill. The sample from the top (slice 2126, analysis 1) has a well-defined trachytic texture, with small granular areas. It is a holocrystalline, moderately fine-grained rock composed of sanidine, anorthoclase, aegirine-augite, sodalite, magnetite and apatite; no nepheline was identified, but Professor Skeats (7) indicates that it was present in the slice examined by him. The felspars are in two generations, the larger being slender, simply-twinned sanidine prisms about 1 mm. long and shorter, broader anorthoclase crystals of ill-defined shape. The smaller felspars are sanidine prisms about 0·2 mm. long. Aegirine-augite occurs as scattered prisms about 0·2 mm. long, and as numerous minute prisms and grains; it is grass green and slightly pleochroic. A colourless, isotropic, allotriomorphic mineral with a low refractive index is identified as sodalite; it is present in small amount only. The identification corresponds with the chlorine determined in the analysis, which would represent about 3·7% of sodalite. Grains and crystals of iron ore, probably titaniferous magnetite, are sparingly scattered throughout the rock. Apatite is present in very small amount as minute, rod-like crystals enclosed in the felspars.

The rock from the flank of Mount Wilson (slice 2272, anal. 2) is porphyritic, consisting of phenocrysts of anorthoclase about 1 mm. long, aegirine-augite (0·2 mm.) and grains of iron ore in a granular groundmass composed of the same minerals together with aenigmatite (cossyrite), sodalite, analcite (?), and olivine. The colourless isotropic mineral seems too abundant to be all sodalite, which (judging by the chlorine content) should not form more than 4% of the rock; possibly some analcite is also present. Aenigmatite (cossyrite) forms small, irregular, brown, strongly pleochroic crystals; it is a rare mineral, but has been identified in the solvsbergites of the Macedon district (3).

The analyses of these two rocks agree fairly closely. Notable features are the high percentages of alkalies and alumina and the presence of chlorine in appreciable quantities. No nepheline or diopside appears in the norm.

Blue Mountain (Wuid Kruirk) is a conspicuous point of eruption on the main divide 3 miles south of Trentham. Like Mount Wilson, it has no crater, and is formed of lava. The flows are of small extent (about 2 or 3 square miles). The rock forming the main mass of the hill closely resembles the rocks of Mount Wilson, but is rather finer in grain. The top consists of a small flow of grey, compact rock, with occasional felspar phenocrysts. Both rocks are anorthoclase-olivine-trachyte.

Microscopic examination of the latter rock (slice 2278, anal. 3) shows that it has a well-defined trachytic texture and consists of sanidine, anorthoclase, aegirine-augite, olivine, iron ores and apatite. The sanidine prisms average 0·5 to 0·8 mm. long and are either simply twinned or untwinned. Anorthoclase forms stouter, irregular prisms and is fairly abundant. Small grains of olivine are scattered through the rock. Apatite forms minute prisms and larger crystals with fibrous inclusions like the apatite in macedonite of the Macedon district (8).

The rock from the lower slopes of the hill also has a trachytic texture, but is not porphyritic. It has the same mineral composition as the rock from the top. The olivine is usually in small grains (about 0·2 mm. across), but occasionally forms larger crystals (about 1 mm. long). Crystals of iron ore are occasionally 0·3 mm. across, but usually much smaller.

These rocks are also high in alumina and alkalies, but they differ from those of Mount Wilson in their lower content of chlorine. Small quantities of both nepheline and diopside appear in the norm.

Pitchstone is fairly abundant on the plateau of volcanic rocks west of the Coliban River, between Spring Hill and the Upper Coliban Reservoir. It is black and glassy with the lustre of pitch. It grades into more lithoidal types, and is associated with grey basaltic rock which breaks like slate. This pitchstone was first recorded by Mr. Dunn(1) as pebbles in the Coliban River below the reservoir, and he had an analysis of one of these pebbles made, as quoted below. Mr. H. Foster found the rock in situ during his geological survey of the Parish of Coliban, and proved it to be part of the Newer Volcanic series. Its chief interest lies in the fact that its silica content is much higher than is usual for our New Volcanic rocks, and that glassy rocks are rare in Victoria. This rock or similar rock from unknown localities was widely used by the aborigines for stone implements. The analysis shows that alkalies are also fairly high, and that, if the magma had crystallised instead of cooling rapidly to form a glass, the rock would be a quartz-trachyte. TiO_2 is high for a rock with such a silica percentage.

Under the microscope (slice 1619, anal. 5), it is a transparent brown glass containing abundant globulites, numerous unidentified minute prisms, larger prisms of pyroxene (about 0·02 mm. long), a little olivine, and occasional felspar microliths. A few pyroxene crystals of considerably larger dimensions, in which are numerous inclusions of glass, also occur. The glass is traversed by lines rendered darker in colour by countless globulites, and these give a flow structure, especially near the larger phenocrysts.

An attempt to plot a variation diagram from the five analyses here given, and Orr's analysis of olivine-anorthoclase-basalt from Daylesford, shows that the oxides do not fall on smooth curves, and suggests local centres of magmatic differentiation.

The olivine-nephelinite from near Drouin comes from a quarry worked for road metal by the shires of Drouin and Warragul in Allot. 91, parish of Drouin West, about 2 miles south of Drouin township. Volcanic rocks in this district extend about 25 miles north and south and 12 miles east and west; they are generally decomposed to deep soils, and outcrops are rare. On the geological map of Victoria they are marked Older Volcanic (that is, Middle or Lower Tertiary), but apart from physiographic considerations and analogy with similar areas in other parts of Gippsland, there is no evidence of their exact age.

Owing to the paucity of outcrops in this area, the nature of the underlying rocks can only be judged from the soil. Samples from quarries near Crossover and near the southern boundary of the Parish of Warragul are olivine basalts.

The quarry where the olivine-nephelinite is worked is situated on the western slope of a small hill which rises to about 700 feet above sea level. Some years ago several bores were put down to test the area of solid rock, and, according to report, it is not more than 2 acres in extent, which suggests that it is a volcanic plug. The surrounding soil is typically volcanic, but it contains fragments of indurated slate and sandstone which are probably ejected blocks. The face of the quarry exposes about 40 feet of solid rock with no signs of successive flows. In some parts a rough columnar structure is developed. The rock is dense and free from vesicles, but contains occasional patches of solid white zeolites, which were probably the final minerals to consolidate from the magma. The rock is excellent road metal.

Under the microscope (slice 2401, anal. 6), it is holocrystalline and panidiomorphic. It consists of nepheline, augite, olivine, iron ore and apatite; felspar is absent. Nepheline forms about one-third of the rock; it is limpid and colourless, and the crystals are from 0·05 to 0·25 mm. across. Augite, the next most abundant mineral, forms greenish prisms about 0·08 mm. long in felted aggregates between the nepheline crystals. Olivine is fairly abundant in crystals about 1 mm. to 1·5 mm. long; it is generally fresh, but is partly altered to serpentine. Abundant cubes of iron ore, probably titaniferous magnetite, are scattered through the rock.

The outstanding features of the Tertiary period in Victoria are vertical earth-movements, extensive faulting and widespread volcanic activity, all no doubt causally connected.

Taking a general survey of the Tertiary igneous rocks of Victoria, so far as they have been examined, we find them to consist of lava flows, tuffs, dykes and volcanic necks, the plutonic equivalents being nowhere exposed. In composition they range from thoroughly basic types, such as limburgites and olivine-basalts, through more andesitic varieties to trachytes, solvsbergites and pitchstones. The olivine basalts are overwhelmingly predominant, but an examination of 37 available superior analyses shows that nepheline appears in the norm, though not in the mode, in about one-third of them. The typical alkaline rocks are sporadic in distribution and of small extent. Taking those mentioned by

Skeats(7), it will be noticed that they lie within or on the edge of the central highland area. To these may be added the crinanites or olivine-analcite-basalts and dolerites in the much-faulted Mesozoic area of South Gippsland. These rocks are abundant, but no modern analyses are available. Old analyses are quoted below, but neither of them separates TiO_2 from Al_2O_3, so that the figures for the latter are too high, probably by 1 or 2 per cent. This will have the effect of making the figures of nepheline in the norm also too high. The analyses, however, are consistent, though by different analysts, and show that the rocks are distinctly rich in soda. Both are coarse grained, ophitic rocks consisting of plagioclase, anorthoclase, augite, olivine, analcite and iron ores, and they resemble the rocks from Camperdown described as essexites.

It appears, then, that the Tertiary igneous rocks of Victoria, and indeed of Eastern Australia, have much in common with the rocks of the Brito-Icelandic petrographic province and with those of the islands of the Pacific Ocean. There also appears to be some evidence to show that the alkaline types are most common in the neighbourhood of extensive faults.

Analyses.

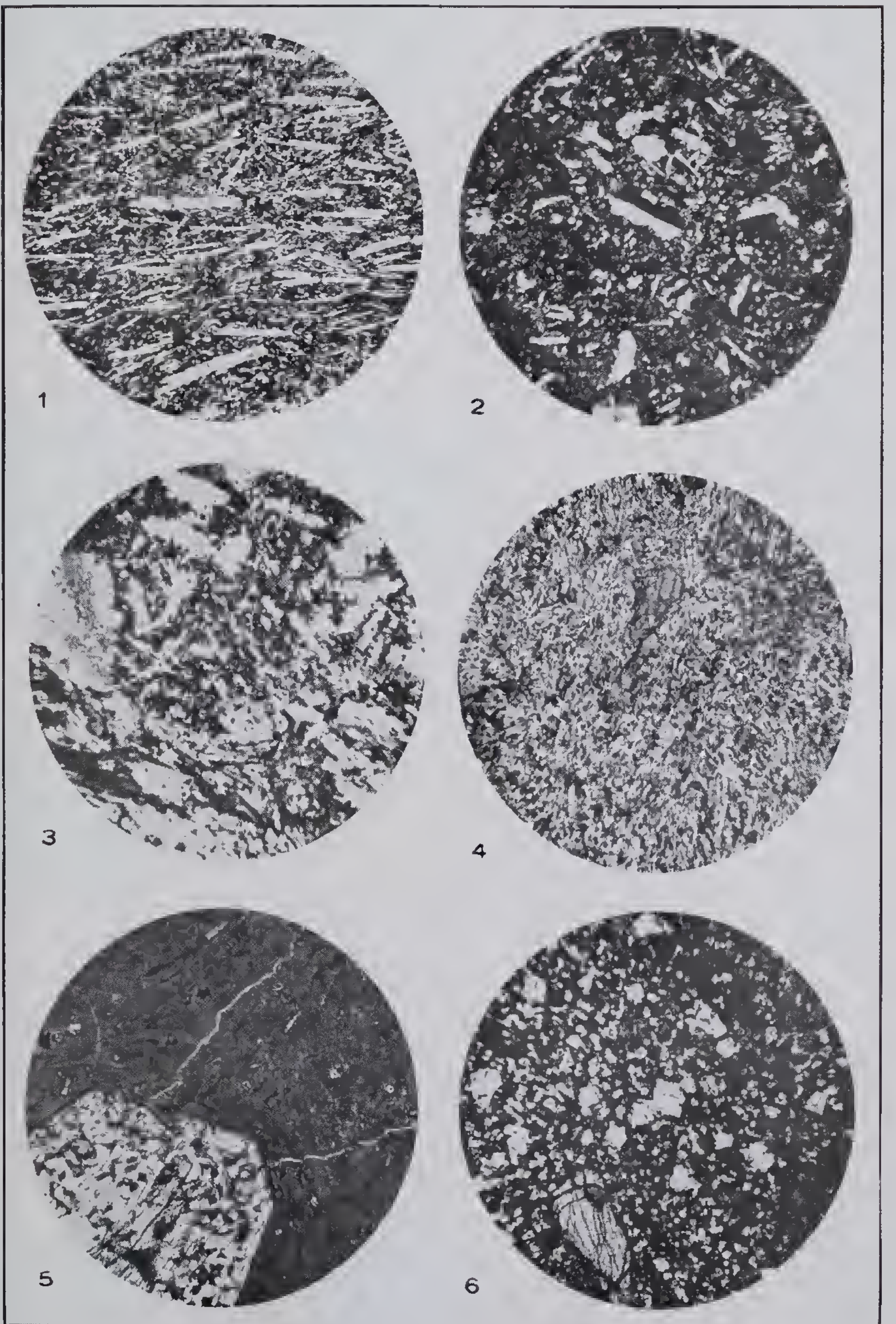
1. Trachyphonolite from top of Mt. Wilson. Analyst, F. F. Field. Pl. VII, Fig. 1.
2. Trachyphonolite from slope of Mt. Wilson. Analyst, F. F. Field. Pl. VII, Fig. 2.
3. Trachyte, top of Blue Mountain. Analyst, F. F. Field. Pl. VII, Fig. 3.
4. Trachyte, Allot. L, Parish of Trentham, lava flow from Blue Mountain. Analyst, F. F. Field. Pl. VII, Fig. 4.
5. Pitchstone, pebble from Coliban River, near railway viaduct, Taradale. Analyst, J. C. Watson. Pl. VII, Fig. 5.
6. Olivine-nephelinite, quarry, Allot. 91, Parish of Drouin West. Analyst, F. F. Field. Pl. VII, Fig 6.
7. Olivine-analcite-dolerite, volcanic neck near Kilcunda Road State School, Parish of Jumbunna East. Analyst, P. W. G. Bayly (1903).
8. Olivine-analcite-dolerite, one and a half miles west of Poowong. Analyst, J. Dennant (1899). See J. Stirling (9).

	1	2	3	4	5	6	7	8
	%	%	%	%	%	%	%	%
SiO_2 -	58·90	58·56	57·49	57·29	63·67	41·13	46·76	47·56
Al_2O_3 -	18·60	20·33	19·14	18·70	15·83	15·74	22·85	16·79
Fe_2O_3 -	3·70	1·71	2·20	1·57	1·39	4·02	3·80	3·05
FeO -	2·30	2·81	4·29	4·67	4·06	7·71	5·83	8·71
MgO -	0·41	0·60	0·65	0·68	2·15	7·98	4·32	6·30
CaO -	1·47	1·85	2·47	3·02	3·88	10·48	8·05	8·57
Na_2O -	6·74	6·56	6·48	5·61	3·57	5·56	5·30	4·96
K_2O -	4·92	4·29	4·90	5·12	3·69	1·12	1·54	1·78
H_2O+ -	1·12	1·12	0·75	1·37	0·02	2·11	1·55	*2·23
H_2O- -	0·79	1·03	0·32	0·48	0·15	0·58	—	—
CO_2 -	nil.	nil.	nil.	nil.	nil.	nil.	—	—
TiO_2 -	0·13	0·14	0·59	0·65	1·27	2·34	—	—
P_2O_5 -	0·09	0·06	0·40	0·36	0·02	0·54	tr.	—
MnO -	0·13	0·19	0·17	0·19	0·43	0·14	—	tr.
Li_2O -	ft. tr.	nil.	sl. tr.	sl. tr.	tr.	sl. tr.	—	—
SO_3 -	nil.	nil.	nil.	nil.	nil.	nil.	—	tr.
Cl -	0·27	0·28	st. tr.	st. tr.	nil.	nil.	—	—
NiO -	—	—	—	—	0·01	—	—	—
CoO -	—	—	—	—	tr.	—	—	—
Total -	99·57	99·53	99·85	99·71	100·14	99·45	100·00	99·95
Sp. Gr. -	2·62	2·63	2·63	2·64	2·569	3·05	—	2·28

*Loss on ignition.

Norms.

	1	2	3	4	5	6	7	8
Q -	nil.	nil.	nil.	nil.	15·49	nil.	nil.	nil.
or -	29·14	25·40	29·03	30·37	21·88	6·64	9·15	10·55
ab -	52·04	53·55	44·21	42·34	30·30	2·26	19·41	16·33
an -	6·75	8·84	8·56	10·60	16·18	14·61	33·94	18·21
ne -	1·70	nil.	5·82	2·85	nil.	24·32	13·84	13·94
C -	0·06	2·03	nil.	nil.	nil.	nil.	nil.	nil.
NaCl -	0·44	0·47	nil.	nil.	nil.	nil.	nil.	nil.
di -	nil.	nil.	0·99	1·83	2·49	27·29	4·99	20·10
hy -	nil.	0·45	nil.	nil.	9·18	nil.	nil.	nil.
ol -	1·64	3·71	4·93	5·55	—	10·23	11·62	14·16
il -	0·24	0·16	1·13	1·23	2·42	4·42	nil.	nil.
mt -	5·37	2·48	3·20	2·27	2·01	5·83	5·51	4·42
ap -	0·19	0·13	0·87	0·78	0·03	1·18	nil.	nil.



J. S. Mann photomicr.

Alkaline Volcanic Rocks, Victoria.